DRAFT

2017-2021 SCIENCE ACTION AGENDA

A COLLABORATIVE ROAD MAP FOR DELTA SCIENCE

DELTA STEWARDSHIP COUNCIL
DELTA SCIENCE PROGRAM

DRAFT 2017-2021 SCIENCE ACTION AGENDA

This public draft 2017-2021 Science Action Agenda was developed by the Delta Science Program working closely with the broad Delta science and management community. Public comment and Delta Independent Science Board review is being sought on this draft. Comments will be considered when finalizing the 2017-2021 Science Action Agenda in early-summer 2017. As specified in the Delta Science Plan, the Lead Scientist for the Delta Science Program will be responsible for articulating the rationale for the Science Action Agenda and its prioritization of science actions.

SUBMITTING PUBLIC COMMENT

Public comments are welcome on this draft 2017-2021 Science Action Agenda. The Delta Science Program encourages written public comments to be submitted to science@deltacouncil.ca.gov. Please organize written comments by section title, heading, appendix, page number, line number and table number.

For public comment on the draft 2017-2021 Science Action Agenda to be considered for incorporation in the final 2017-2021 Science Action Agenda, comments must be received no later than Wednesday, May 10, 2017. Additional time may be granted to the Delta Independent Science Board for their review.

THE FOLLOWING POINTS ARE RELEVANT TO THIS DRAFT 2017-2021 SCIENCE ACTION AGENDA

List of Contents is not in final format.

List of acronyms is under development and will be completed in a final version.

Technical editing for all information in the Draft 2017-2021 Science Action Agenda, including grammatical and style changes, will be ongoing.

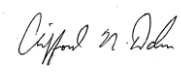
Layout, tables, and figures are preliminary or undergoing development. New figures will be inserted as they are completed.

Foreward

There are pragmatic and aspirational reasons for a Delta-wide science action agenda. Pragmatically, the Delta Science Plan (completed in December of 2013) calls for "the open and inclusive development of a science action agenda to organize, integrate, and prioritize science activities across agencies and programs to address decision-makers' grand challenges." The Delta Science Program has been working diligently to complete the many tasks in the Delta Science Plan, and finalizing the 2017-2021 Science Action Agenda is an important achievement. However, I also see a compelling aspirational reason for developing the 2017-2021 Science Action Agenda. This is based on insights I gained as a Program Director in the Ecosystem Studies Program at the National Science Foundation (NSF) in the Division of Environmental Biology. There was within NSF a keen awareness that certain scientific disciplines were particularly well-organized and forward-looking in terms of the science that needed to be done to most effectively advance the discipline. When I was at NSF, the astronomers, oceanographers, and physicists were especially proficient at advancing an agenda and speaking with a unified voice. My hope is that the 2017-2021 Science Action Agenda can have a similar organizing and catalyzing impact on Delta science. Science investments are often justified and awarded to communities of scientists who are able to successfully coalesce around a clear set of priority science actions and science infrastructure needs.

Another important insight I gained from my time at NSF was the critical need to invest in stable long-term studies. Visionary program directors at NSF initiated the Long-Term Ecological Research (LTER) network in 1980. The network is based upon the realization that ecosystem change commonly pivots on rare extreme events. The LTER network was and remains a key part of the science enterprise support by the Division of Environmental Biology and NSF. The Delta and Bay are exceptionally fortunate to have similar long-term data sets. Supporting the continuation of increasingly valuable long-term data bases and linking new and emerging research to these foundational data sets represents an overarching goal of the 2017-2021 Science Action Agenda.

To truly advance scientific knowledge and provide the science-based tools needed to support decision-makers and resource managers tasked with addressing wickedly complex issues in the Delta, a collective identification and ownership of science priorities is needed to inform strategic science investments. This 2017-2021 Science Action Agenda for the Delta came from the input of literally hundreds of scientists and science managers and hopefully represents a road map to help us come together around a common set of priorities that no single organization has the capacity to achieve on its own. It is my hope that this agenda will set a clear pathway for establishing partnerships and securing investments to advance relevant, credible, usable, and creative science in the Delta.



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List of Acronyms

CAMT	Collaborative Adaptive Management Team
CSAMP	Collaborative Science and Adaptive Management Program
DRMP	Delta Regional Monitoring Program
ESA	Endangered Species Act
IEP	Interagency Ecological Program
ISAA	Interim Science Action Agenda
MAST	Management, Analysis, and Synthesis Team
SAA	Science Action Agenda
SAIL	Salmon and Sturgeon Assessment of Indicators by Life stage
SBDS	*The State of Bay Delta Science*
SFCWA	State and Federal Contractors Water Agency

Preface

This document presents 12 priority science actions that fill critical gaps and provide glue for the Delta science enterprise to advance the vision of the Delta Science Plan: *One Delta, One Science*. The table on the following page provides a summary of 12 high priority science actions organized under five thematic science action areas that were identified through an open and transparent prioritization process that involved input from the Delta Science community, major synthesis efforts, and key peer-reviewed literature. The document then details each action area and discusses how this document can be used to promote collaborative science, improve efficiencies in science planning, and coordinate investments in critical science investigations and infrastructure.

Summary of Priority Science Actions

Table 1. A summary of the 12 priority science actions organized into five action areas.

Action Area 1: Improve understanding of interactions between stressors and managed species and their communities
A. Implement studies to understand the ecosystem response before, during, and after the Sacramento Regional Wastewater Treatment Plant's EchoWater Project upgrades.
B. Identify areas that act as refugia for species of concern during extreme conditions, particularly drought and flood, to inform management decisions and priorities during extreme climate events.
Action Area 2: Capitalize on existing data through increasing science synthesis
A. Strategically build the capacity to do collaborative science and science synthesis through implementing the science synthesis mechanisms outlined in the Delta Science Plan.
B. Identify and prioritize the most used data sources that should be interconnected to promote collaboration and provide the technology needs that will allow this information to be easily available through web-based services.
Action Area 3: Develop tools and methods to support and evaluate habitat restoration
A. Develop methods for evaluating long-term benefits of habitat restoration based on current understanding of how species use restored areas.
B. Estimate and assess the effects of location and sequence for initiation of tidal marsh habitat restoration projects/investments with ongoing sea-level rise and climate change.
Action Area 4: Invest in assessing the human dimensions of natural resource management decisions
A. Investigate the most cost-effective methods to improve habitat for species of concern on working lands.
B. Develop an evaluation and feasibility process for addressing fish passage at California's rim dams to inform a rim dam solution plan that integrates economic and environmental goals.
C. Determine how to coordinate and assist the application of adaptive management in the Delta.
Action Area 5: Modernize and improve monitoring, data management, and modeling
A. Develop a federated system of data bases linked and assessed through web services designed to support modeling and management decisions to provide timely public access to information using open data formats.
B. Establish an open Delta Modeling Collaboratory (physical or virtual) that promotes the use of models in guiding policy.
C. Invest in innovative technologies and cost-effective methods for scientific monitoring and analysis.

Introduction

Why a 2017-2021 Science Action Agenda?

"Union gives strength." – Aesop's Fable, 'The Bundle of Sticks'

A collective action is needed to advance scientific discoveries, sustain essential existing science programs, and modernize the Delta science enterprise.[1] The 2017-2021 Science Action Agenda (SAA) is a critical element in the process of achieving this goal because the SAA defines and communicates a shared set of priority actions for guiding and integrating science activities across multiple programs and agencies in the Delta.

What sets the SAA apart from other strategic science efforts? The SAA identifies science actions that otherwise fall between the mission statements and priorities of a single group, program, or agency but are otherwise recognized as critical actions that address key management needs. The SAA builds on the essential activities of existing collaborative efforts such as the Interagency Ecological Program (IEP), Collaborative Science and Adaptive Management Program (CSAMP), Delta Regional Monitoring Program (DRMP), and State and Federal Contractors Water Agency's (SFCWA) Coordinated Science Program. It fills gaps and serves as the glue for synergistic and multi-benefit science to support management needs. Another key element of the SAA is that the science actions emerged out of a transparent and open process. Participants in the overall Delta science enterprise and the Delta Science Program's Science Advisory Committee have provided input to ensure that the Delta science community supports these actions to be of high importance.

The 2017-2021 SAA furthers the vision of the Delta Science Plan [2]: *One Delta, One Science*.[2] The Delta Science Plan (adopted in December 2013) itself is a shared document, developed jointly to guide integrated, collaborative, and transparent science to enhance policy and management in the Delta. The purpose of the SAA is to bring the broad Delta science enterprise together in identifying and jointly implementing a common playbook for strategically driving science and decision-making over a four-year timeframe.

[1] Science Enterprise is not interchangeable with "science program." Instead, it refers to the collection of science programs and activities that exist to serve managers and stakeholders in a regional system. The elements of an enterprise range from in-house programs within individual agencies or other organizations to large-scale collaborative science programs funded by governments. Included in this definition is academic research, recognizing that academic researchers often operate independently of management and stakeholder entities. Science enterprises can vary greatly in the degree to which resources are concentrated in collaborative programs and produce publicly-available results. The differences among regional systems can reflect historical factors, depth and persistence of conflict regarding resource issues, governmental guidance and engagement, the range of agencies and interests involved, and other factors. [1]

[2] *One Delta, One Science* means an open Delta science community that works collaboratively to build a shared body of scientific knowledge with the capacity to adapt and inform future water and environmental decisions.

What is the 2017-2021 Science Action Agenda?

The SAA is a four-year science agenda for the Delta, which prioritizes and aligns science actions to fill gaps in knowledge and inform management decisions, promotes collaborative science, builds the science infrastructure, and achieves key objectives of the Delta Science Plan. This document will be the first full SAA to be completed as called for in Action 2.2 of the Delta Science Plan [2].

The SAA is one element of a three-part Delta Science Strategy that also includes the Delta Science Plan and *The State of Bay-Delta Science* (SBDS). These three elements build upon one another to support *One Delta, One Science*; the Delta Science Plan being the foundation that sets a shared vision of Delta science, while SBDS synthesizes scientific knowledge in the Delta and provides the SAA with information to begin identifying priority science actions to address key uncertainties and fill institutional gaps. This 2017-2021 SAA identifies priority science actions for the Delta founded on *The State of Bay Delta Science* 2016 and completed interim SAA efforts (i.e., the 2014 Interim Science Action Agenda and High-Impact Science Actions).

The 2017-2021 SAA does not cover every important science action underway in the Delta. Essential science and scientific monitoring efforts are taking place across the landscape of the Delta science enterprise. For example: long-term monitoring to comply with federal and State regulatory requirements (e.g. IEP) and scientific research and synthesis efforts that advance scientific discovery and the state of knowledge on topics like predation [3, 4], the role of harmful algal blooms [5], groundwater supply and demand [6], and more. Rather, the 2017-2021 SAA serves as the "gaps and glue" among existing science efforts in the Delta. These science activities are not fully addressed despite being recognized as cross-agency and multi-group priorities, feasible to implement and preform, and opportunities to promote collaborative efforts. Implementing these science actions is important to filling critical knowledge gaps and building science capacity to address today's management problems, challenges on the horizon, and anticipated or existing long-term science issues.

There are 12 priority science actions in the 2017-2021 SAA. The 12 science actions in this SAA emerged as the highest priority science actions based on applying the prioritization criteria to 161 science actions that were collated from over 550 science actions sourced from scientific reports, work plans, synthesis efforts, surveying scientists and science managers, and targeted outreach to the Bay-Delta science community. The criteria used to prioritize science actions included scientific merit, level of impact, timeliness, and the relative cost of inaction (See Appendix B for complete methods). These 12 actions are presented as the highest priority science actions to initiate between 2017 and 2021 to address pressing management needs.

The 12 priority science actions are organized into five priority science action areas. The five action areas are naturally and purposefully integrative to support the complexity of Delta water and environmental management challenges. For example, managing Delta water and environmental resources affected by major stressors such as climate change, increases in temperature, altered flow regimes, loss of habitat, and evolving contaminant and nutrient compositions will require portfolio investments in science and infrastructure that test novel hypotheses, modernizes the way we collect and share information, and builds capacity and expertise to systematically synthesize current understanding.

These science actions were organized and prioritized by the Delta Science Program with leadership from the Delta Science Program's Lead Scientist, the IEP Lead Scientist, and through an inclusive process that

regularly engaged the Delta science enterprise with considerable input from the Delta Agency Science Workgroup.

Science Action Areas

Five overarching thematic science action areas were identified in which to invest resources:

1. Improve understanding of interactions between stressors and managed species and their communities
2. Capitalize on existing data through increasing science synthesis
3. Develop tools and methods to support and evaluate habitat restoration
4. Invest in assessing the human dimensions of natural resource management decisions
5. Modernize and improve monitoring, data management, and modeling

These action areas and the 12 prioritized science actions are intended to be responsive to current and future management and policy needs. However, if a major catastrophe or rare event (e.g., damaging earthquake, severe flood, contaminant oil spill, prolonged drought) occurs that transforms the Delta landscape and/or infrastructure during the timeframe of this SAA, the Delta Science Program will work openly and transparently with the Delta science, management, and policy communities to make adjustments to the prioritized actions to be nimble and responsive to new needs without fully compromising the near-term investments needed to yield desired long-term dividends.

How should the 2017-2021 Science Action Agenda be used?

The 2017-2021 SAA should be used to guide science planning and marshal funding across all science endeavors in the Delta. This includes agency, academic, private, and non-governmental institutions. Specific uses of the SAA include informing competitive solicitations for science proposals, agency budget change proposals, coordinated multi-agency efforts, and informing updates to individual science program strategic planning efforts.

The 2017-2021 SAA also serves as a tool for communicating collaborative Delta science priorities within and outside of the system and can be used to clarify the opportunities for improving alignment of the actors and institutions in the Delta science enterprise. The SAA should also guide existing collaborative and individual science organizations in pointing their efforts in a common direction to collectively advance scientific insights and ensure a robust science infrastructure for supporting management and policy decision-making.

Science Action Areas and Priority Science Actions

Below are the 12 priority science actions (in bold) organized into five action areas. The 12 science actions are intentionally broad to be inclusive of a range of science questions and approaches for achieving the action to address key management needs. These management needs are ordered to correspond with the respective science actions within each action area and are accompanied by specific example questions that are highlighted in the introductory text beneath each science action area. Under each prioritized science action, examples of science questions or specific potential actions are provided to explain how the priority science action could be addressed consistent with management needs. These are not comprehensive examples. It is fully recognized that other science questions and potential

actions could be implemented to achieve the objectives of the science actions to address management needs.

The science action areas are not themselves prioritized or intentionally ordered. There may be important sequencing to some of the priority science actions that should be considered upon implementation. Implementing science actions within one action area before another science action in another action area may maximize returns on investments. However, to retain nimbleness and opportunistic pathways to pursue resources, potential sequencing is not reflected here.

1. Improve understanding of interactions between stressors and managed species and their communities

In the Delta, stressors are factors that negatively affect species and their communities with the most notable impact manifesting in the often precipitous decline of native species populations [7, 8]. Prominent stressors include increasing climate variability; increases in temperature; loss in habitat; and changes in flow, contaminants, and nutrient concentrations. The negative role stressors play in the Delta is well acknowledged [7, 9-11], but it is very difficult to design and implement management actions that holistically address multiple and interacting stressors on species and their communities. It is important to consider the coupled-human and natural system while also supporting current regulations that are structured around single species or chemical constituents (e.g., federal and State Endangered Species Acts and the federal Clean Water Act).

Management Needs

A. Develop conceptual and numeric models to enhance understanding to inform nutrient management questions.[3, 12, 13]

   Example question: How will the large-scale nutrient loading change resulting from the Sacramento Regional County Sanitation District wastewater treatment plan upgrade affect nutrient cycling, primary production, and important food webs within the Delta?

B. Quantify the effects of climate change on species, Delta ecology, and potential impacts on water and natural resource management.[14]

   Example questions: How far will species suites move in response to changes in climate? How do species utilize lands adjacent to habitat restoration sites during extreme events?

Priority Science Actions

A. Implement studies to understand the ecosystem response before, during, and after the Sacramento Regional Wastewater Treatment Plant's EchoWater Project upgrades.[15]

   Example science questions: What do we know about current ecosystem responses to the existing nutrient loading regime? Where are the 'hot spots' of nutrient transformations and uptake in the Delta that traditional monitoring methods miss?

B. Identify areas that act as refugia for species of concern during extreme conditions, particularly drought and flood, to inform management decisions and priorities during extreme climate events.[16]

Example science questions: How have agricultural areas served as refuge areas during extreme conditions for affected species? What are the physical and biological characteristics of historical areas that acted as drought and flood refugia for affected species?

2. Capitalize on existing data through increasing science synthesis

In order to provide a reliable knowledge base for decision-making in this dynamic and wickedly complex environment, science synthesis, or the act of "distilling existing data drawn from many sources across multiple fields to accelerate the generation of new scientific knowledge at a broad scale" [17, 18] is critical. Science synthesis is important for maximizing the effectiveness of science in supporting management decisions by managing conflict over data interpretation [2].The science actions presented in this action area emphasize the need for implementing the Delta Science Plan's mechanisms and protocols for ongoing synthesis in a way that is strategic and relevant to management issues. The Delta Science Plan calls for fostering integrative synthetic thinking throughout the Delta science and management community through multi-year endeavors such as the SBDS or shorter time scale efforts like workshops, peer-reviews, and white papers that accelerate our understanding of the system to provide information for managers and policy makers [2].

Existing programs and efforts that serve as prime examples of strategic synthesis include the IEP Management, Analysis, and Synthesis Team (MAST) and Salmon and Sturgeon Assessment of Indicators by Life stage (SAIL) groups and the nutrient research plan science workgroups. These groups have provided information heavily relied upon by recent management initiatives such as the Delta Smelt Resiliency Strategy, Nutrient Research Strategy, State Water Resource Control Board's Phase I Substitute Environmental Document for the Water Quality Control Plan, and draft Biological Opinions related to the California WaterFix.

Management Needs

A. Be nimble and responsive to new demands, including non-routine and opportunistic science needs.[14]

Example question: What scientific lessons can be learned from past drought management actions coupled to fish migration and survival studies to inform future management efforts?

B. Improve data and information exchange.[14]

Example question: How can we collaborate among various agencies to negotiate sharing of data and improve data accessibility, building on efforts such as SacPAS, to create a publicly available web-based query system that provides real-time information?

Priority Science Actions

A. Strategically build the capacity to do collaborative science and science synthesis through implementing the science synthesis mechanisms outlined in the Delta Science Plan.[2, 14]

Potential action: Implement a Delta Collaborative Analysis and Synthesis effort to address the abundances and relative distributions of Delta Smelt and Longfin smelt in different Bay- Delta habitats (i.e., shallow water, tidal wetland, open water) and at different life stages.

B. Identify and prioritize the most used data sources that should be interconnected to promote collaboration and provide the technology needs that will allow this information to be easily available through web-based services.[15]

Potential action: Integrate data that focuses geographically on the Cache Slough Complex into a portal section on the My Water Quality page.

3. Develop tools and methods to support and evaluate habitat restoration

For more than a century and a half, management actions and human alterations to the landscape have reduced vast swaths of native and migratory species' habitat in the Delta to small fragmented parcels [19]. This loss of habitat, coupled with stressors described in the first action area, has severely compromised the historical Delta ecosystem and its native species. In response to declining species populations and overall ecosystem health, there have been increased efforts to restore natural processes and improve the ecological functions of the Delta as called for in the Delta Reform Act (e.g., Delta Plan, Ecosystem Restoration Program, EcoRestore, CA Department of Fish and Wildlife's Delta Conservation Framework, and Delta Conservancy's Strategic Plan). In addition, regulatory actions, such as the U.S. Fish and Wildlife Service's 2008 Biological Opinion and National Marine Fisheries Service's 2009 Biological Opinion, mandate habitat restoration to improve current conditions for threatened and endangered fish species and their communities. Advanced tools and methods are needed to plan and implement projects in an integrated, consistent, and systematic way while applying the principles of adaptive management framework as called for in the Delta Plan.

Management Needs

A. Evaluate success of restored areas on a landscape scale.[16, 20]

Example question: How do native (including ESA-listed) species and non-native species use restored habitats?

B. Effectively plan restoration, recovery, enhancement and mitigation projects, troubleshoot their problems, and assess their cumulative effects.[20]

Example question: How do tidal wetland projects impact physical (e.g., tidal dynamics) and ecological (e.g., food web dynamics) characteristics of the Delta? What are the most effective designs for tidal restoration sites to achieve tidal flow velocities that preclude rooting by invasive aquatic vegetation?

Priority Science Actions

A. Develop methods for evaluating long-term benefits of habitat restoration based on current understanding of how species use restored areas.[16, 21]

Example science questions: How do different channel morphologies and channel margin habitats affect native fish species and communities? To what extent do invasive species influence the suitability of restored habitats for target species?

B. Estimate and assess the effects of location and sequence of tidal marsh habitat restoration projects/investments with sea-level rise and climate change.[14]

Example science question: How do large-scale tidal wetland restoration actions affect tidal excursion, bathymetry, the low salinity zone, and sediment dynamics in the estuary?

4. Invest in assessing the human dimensions of natural resource management decisions

Humans are inextricably linked with the Delta ecosystem. Investments in social and behavioral sciences (e.g., economics, sociology, and psychology) that assess the human aspects of natural resources management actions have been minimal compared to biological and physical sciences in the Delta. Despite increasing awareness of the importance of integrative and transdisciplinary research, the Delta is not alone in its struggle to integrate social sciences into its science programs when compared to other large estuarine and coastal systems in the United States [1]. There is a growing recognition that investments in science to understand human responses to management actions, holistically evaluate value-based tradeoffs among management alternatives, and assist with balancing limited resources among human and wildlife uses are important for creating novel policies and durable natural resource management solutions.

Investments in science that explores the human dimensions of management actions is especially important in the Delta because the Delta Reform Act states that the coequal goals of a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem shall be achieved in a manner that protects the unique cultural, recreational, natural resources, and agricultural values of the Delta as an evolving place (CA Water Code §85054). An initial review by the Delta Independent Science Board recommends establishing ongoing research on the Delta as an evolving place that is substantial and integrated with Delta research in other areas such as habitat restoration, flow requirements, or water quality [22]. The following priority actions aim to integrate the human dimension of resources management issues into science-based tools that support adaptively managing habitat restoration efforts, considering the utility of citizen science monitoring programs, and holistic synthesis efforts.

Management Needs

A. Identify policy alternative and potential incentives for changing human behaviors to improve species' habitat conditions.[14, 23]

Example question: Are financial subsidies effective in increasing wildlife-friendly agriculture on private lands?

B. Determine how water project operations affect salmon population dynamics and survival within the Delta's complex channel network to guide water operations, timing, provide early warning, and accelerate recovery efforts and habitat restoration design.[24]

E*xample question: Is trucking salmon around dams a viable conservation practice?*

C. Effectively plan restoration, recovery, enhancement and mitigation projects, troubleshoot their problems, and assess their cumulative effects.[20]

Example question: How can we improve the way we share lessons learned, communicate ideas and information on adaptive management, and provide a networking venue for project implementers, managers, and scientists?

Priority Science Actions

A. Investigate the most cost-effective methods to improve species' habitat on working lands.[23, 25]

Example science question: What are the behavioral responses associated with various incentive programs to create wildlife-friendly agriculture and which of these programs is the most cost effective?

B. Develop an evaluation and feasibility process for addressing fish passage at California's rim dams to inform a rim dam solution plan that integrates economic and environmental goals.[14, 23, 26]

Example science question: How does human-assisted fish passage at dams affect the viability of salmon populations? What factors should be considered when prioritizing construction of fish passage facilities?

C. Determine how to coordinate and assist adaptive management in the Delta.[27]

Potential science actions: Coordinate adaptive management experts (e.g., agency leaders, resources managers, practitioners, scientists, and stakeholders) to better implement the Delta ISB's recommendations on Adaptive Management. Design monitoring protocols to fit the magnitude of management actions and the timing of important ecosystem processes that make the value of adaptive management more readily apparent. Model alternative future scenarios and predict system-wide responses using interdisciplinary teams.

5. Modernize and improve monitoring, data management, and modeling

A comprehensive monitoring program paired with infrastructure that supports an intuitive, streamlined system for accessing data to support management actions are key aspects of a robust science enterprise [1, 28]. In the Delta, this concept is especially relevant given the rapidly evolving nature of the region [18]. We need tools that will allow us to be nimble and well-coordinated in the face of growing uncertainty. Existing computational models (e.g., DSM2, RMA2, and SCHISM) have been instrumental in informing management actions through improving our understanding of monitoring data and our conceptual thinking of the Delta [26, 29]. Recent management actions that have relied heavily on Delta models include temperature plans for the Sacramento River, assessing the ecosystem effects of the Emergency Drought Barrier on False River, and supporting the development of draft Biological Opinions for various fish species that may be impacted by the California WaterFix. In addition to simulating different management approaches and scenarios, models can help predict emerging issues and lessen potential unwelcome surprises.

The information a model provides is only as strong as the data upon which the model is based on and accessibility of the model to the wider Delta community. Thus, for current models to perform optimally and new enhanced tools to be developed, we need robust data management systems and well-established monitoring programs that collect continuous, comprehensive, and long-term data sets. Developing a "data stewardship" [30] that provides wide access to information for answering key management questions is also critical for forward thinking, nimble, and coordinated decision making [26, 28].

Management Needs

A. Improve data and information exchange.[14]

Example question: How can information be more efficiently shared to inform environmental permitting processes and real-time water operations?

B. Utilize models of the Delta and visualization tools that are widely accessible and sustained by multiple sources to predict and assess the likely outcomes of management actions and environmental change.[14]

Example question: How can landscape changes in the Delta be best visualized under various earthquake scenarios?

C. Be nimble and responsive to new demands, including emerging and opportunistic science needs.[14]

Example question: What should we invest in to slow and contain the spread of invasive species in the Delta?

Priority Science Actions

A. Develop a federated system of data bases linked and assessed through web services designed to support modeling and management decisions to provide timely public access to information using open data formats.[31]

Example science question: How can information be more efficiently shared to inform environmental permitting processes and real-time water operations?

B. Establish an open Delta Modeling Collaboratory (physical or virtual) that promotes the use of models in guiding policy.[31]

Potential science action: Convene community modelers to develop decision-support tools to address management questions identified in the Effects of Water Project Operations on Juvenile Salmonid Migration and Survival in the South Delta; Volume 1: Findings and Recommendations *[32].*

C. Invest in innovative technologies and cost-effective methods for scientific monitoring and analysis.[21, 23, 33, 34]

Potential science actions: Develop improved survey equipment such as: high frequency water quality and nutrient sensors, drones, environmental deoxyribonucleic acid (eDNA), acoustic tag technology for small fishes, natural tags, improved tools for fish monitoring, phone applications, camera technology, LiDAR, and high resolution bathymetry surveys. Improve modeling and tools for assessing levee integrity and design citizen scientist monitoring programs.

Science Infrastructure

Critical infrastructure underpins the science enterprise in the Delta. Long-term sustained support for current infrastructure and investments in new tools and capacity guarantees a vibrant Delta science program. Many of the priority science actions identified in this agenda require continued or new investments in the form of physical, computational, virtual, and human infrastructure. Examples of valuable physical infrastructure include:

- Acoustic Doppler Current Profilers (ADCP) – networks of instruments to measure three-dimensional (3D) water current velocities and Delta flows
- Continuous Real-Time Water Quality (RTWQ) Stations – real-time telemetered sensor networks for measuring Delta temperature, specific conductance (salinity), pH, turbidity, dissolved oxygen, chlorophyll, nitrate, phosphate, ammonium, and fluorescence
- Acoustic Telemetry Tags and Receivers – networks for tagging and remote tracking of fish in 3D throughout the Delta
- Environmental Genomics and eDNA Monitoring – rapid monitoring of aquatic distribution and abundance directly from Delta water samples.

Such infrastructure provides critical tools for informing real-time operations and water quality management. In addition, supporting virtual infrastructure for open and transparent sharing of water and environmental data increases the capacity for collaborative science synthesis, facilitates innovative ways to share data across agencies and organizations, and sets the stage for developing a federated data sharing system.

These examples and others not called out here show how even single one-time investments in long-term infrastructure can have widespread impacts in moving multiple priority science actions forward. Future funding for infrastructure deserves to be promoted as high priority and should capitalize on facilitating the implementation of multiple needs that broadly serve the Delta science enterprise.

Next Steps

Success of the 2017-2021 Science Action Agenda relies on the dedication of the Delta science enterprise to work intentionally and collectively to fill these priority science gaps and glue to advance science that is readily usable for decision-making. This includes actively seeking partners to support and fund these science actions. Example mechanisms include, but are not limited to, joint competitive solicitations for science proposals and coordinated agency budget change proposals. This is designed to be the community's science action agenda; its success relies on joint commitment to its promotion, advancement, and accomplishment.

The following measures will be used to evaluate our collective success in implementing the 2017-2021 Science Action Agenda:

- Scientific knowledge about the Delta is effectively advanced and communicated
- Knowledge gaps and recommendations identified in SBDS 2016 are addressed and progress made
- Management and policy decisions are founded on science that results in achievement of actions presented in the 2017-2021 Science Action Agenda
- Science infrastructure is modernized and able to learn from novel and opportunistic events (e.g., levee failures, severe floods, earthquakes, prolonged droughts, introductions of new invasive species, chemical spills)
- The action areas and 12 priority science actions are used to inform proposal solicitation packages, requests for proposals, or other mechanisms for selecting and funding science activities
- The 2017-2021 SAA is noted and referenced when communicating regional science priorities
- The Delta Independent Science Board uses the 2017-2021 SAA to assist in reviews of science programs in the Delta
- The Delta Science Plan's strategic actions (e.g. improve data management and accessibility, integrate synthesis for system-wide perspectives, engage in adaptive management) are advanced and/or achieved

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Appendix A: Second Tier Science Actions

Below are science actions that were part of the initial Short List of 27 science actions. These are recognized as important actions and should be addressed as funds become available and higher priority science actions are addressed.

1. Improve understanding of interactions between stressors and managed species and their communities

Science Action	Management Need
A. Understand mechanisms for observed relationships between flows and aquatic species assemblages.[1, 2]	Determine how water operations and restoration actions will affect Longfin Smelt to adaptively guide management decisions and restoration design (e.g., will augmented spring outflow be required to maintain Longfin Smelt abundance?).[3]
B. Better understand salmonid temperature tolerances in streams.[1]	Predict how environmental stressors will affect the health condition of salmonids in the Bay-Delta, migratory corridors and natal tributaries (e.g., what is the relative importance of temperature mortality in the salmon life cycle?).[4]
C. Evaluate the effects of toxicity (e.g., contaminant mixtures, pharmaceutical products, HABs) on aquatic species' survival including possible effects on predation risk.[1, 2, 5, 6]	Identify and forecast which water quality contaminant sources and processes are most important to understand and quantify (e.g., What are the three most important toxins contributing to Delta Smelt impairment, mortality, or physiological stress?).[3, 5, 7, 8]

2. Capitalize on existing data through increasing science synthesis

Science Action	Management Need
A. Continued study of relative cohort abundance with data from Sturgeon study, Sturgeon fishing report card, bycatch in California halibut trawl, and surveys in non-natal estuaries. Use synthesis and modeling of this information to develop improved abundance estimates.[4]	Develop population abundance estimates and trends for Green and White Sturgeon (e.g., use model outputs to evaluate trends in Green Sturgeon abundance).[9]
B. Produce a meta-analysis of existing telemetry results to provide more general conclusions from the various telemetry datasets.[1]	Knowledge of predator-prey relationships and how changes in flow, climate, and habitat may affect these relationships (e.g., what are the best predator reduction techniques and which are feasible, most effective, and best minimize potential impacts on listed species?).[5, 10, 11]

3. Develop tools and methods to support and evaluate habitat restoration

Science Action	Management Need
A. Review efforts to examine effectiveness of habitat restoration.[3]	Understand how species use restored areas (e.g., how does tidal marsh restoration affect production of food suitable for listed fish species both within and outside of restored sites?).[3, 10]
B. Collect environmental, social, and economic baseline data and develop a database of pre-project habitat conditions at the landscape scale (e.g. native species presence/condition, water quality, current food and predator densities, conditions in adjacent channels, and socio-economic valuations of management practices and environmental stewardship).[3, 12]	Evaluate success of restored areas on water quality on a landscape scale (e.g., to what extent does intertidal wetland restoration result in changes in contaminants such as mercury and photochemically active organic compounds that could affect listed fishes?).[3, 13]

4. Invest in assessing the human dimensions of natural resource management decisions

Science Action	Management Need
A. Implement studies to understand socio-economic adaptations to climate change (e.g., human behavioral response in the agriculture sector to changes in water prices).[1, 6]	Quantify the effects of climate change and extreme events on agriculture and economy to inform adaptation strategies (e.g., potential for flood risk, how will increasing temperatures affect regional crop mixes, water pricing, and employment?).[3, 6]
B. Develop a methodology for assessing the long-term costs and benefits of managed wetlands and ponds.[13]	Evaluate success of restored areas on a landscape scale (e.g., do the habitat benefits of managed wetlands and ponds outweigh potential costs to native species?).[3, 13]

5. Modernize and improve monitoring, data management, and modeling

Science Action	Management Need
A. Build on existing models to integrate fish and water quality monitoring data to report, simulate, and forecast distribution of salmon runs in time and space. These actions should be coordinated with tagging studies and other monitoring data to provide accurate and consistent interpretation of information to support decision makers (e.g., coupling 3-D hydrodynamic modeling of the Delta with juvenile salmon behavior and survival).[2, 4, 14]	Determine how water project operations affect salmon population dynamics and survival within the Delta's complex channel network to guide water operations timing, provide early warning, and accelerate recovery efforts and habitat restoration design (e.g., quantitatively understand salmon distribution and movement for real-time water operations).[15]
B. Conduct baseline surveys throughout spawning habitat, map egg collection and larval rearing habitat, and quantify availability using various characteristics	Identify Green and White Sturgeon habitat usage and attributes to guide resource allocations for their protection, conservation, and recovery (e.g.,

	identified through egg sampling (water temperature, depth, velocity, substrate, etc.).[9]	what is the potential effect of flow and temperature on Green and White sturgeon spawning?).[12]
C.	Develop and implement a Bay Area and Delta regional wetland monitoring program.[13]	Improved monitoring to include more relevant information about health, distribution, and abundance of wetland species in light of climate change uncertainty (e.g., what opportunities exist for joint implementation of Regional Water Quality Control Board regions 5 & 2 monitoring plans?).[3, 13]

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Appendix B: Science Action Agenda Development Process

Introduction and Background

Delta Science Plan Action 2.2 calls for the development, implementation, and update of a Science Action Agenda that organizes, integrates, and prioritizes science activities across agencies and programs to address decision-makers' needs in an efficient manner. The Interim Science Action Agenda (ISAA) effort took an initial step toward achieving this action while also providing the foundation for the High-Impact Science Actions, a list of high-impact, multi-benefit science actions for immediate implementation in 2015-2016.

Prioritization of science activities for the Science Action Agenda were developed and updated through an open process led by the Delta Science Program. The following is a record of the methods that were taken to identify a draft list of priority science actions for inclusion in the Science Action Agenda. The process began with an outreach effort to communicate the Science Action Agenda's purpose and to solicit recommendations for science actions and management needs, followed by application of a draft set of prioritization criteria to the list of science actions, a brainstorming session to incorporate more social science aspects in the current list of science actions, and review of the refined list by the Delta science community.

Initial List Development (May 2016 – November 2016)

An initial list of key management actions and associated science actions were compiled based on science actions identified in the Interim Science Action Agenda (ISAA), documents listed in Table 1, and from outreach efforts, described in the section below. To minimize repeating efforts conducted while developing the ISAA, the literature review was limited to the ISAA and documents related to collaborative groups in the Delta, which provided a good representation of management needs and science actions shared by Delta-wide communities. A list of 557 combined management needs and associated science actions were compiled from these sources. A copy of the Master List can be found here: https://deltacouncil.box.com/s/34dnzx5gbt70jw80b2wlovn1smqbnerp.

Screening and Prioritization Criteria Development (May 2016 – October 2016)

The set of prioritization criteria was developed as an approach in identifying priority science actions to achieve the vision of *One Delta, One Science* with substantive input from others. The criteria were developed using examples from several sources found in Table 2.

Two sets of criteria were developed: screening criteria, which were applied to refine the Master List and science prioritization criteria to prioritize the refined list. Below are the overarching criteria. A detailed description of each set or criteria can be found in the SAA Draft Prioritization Approach, Appendix C and a summary of the criteria is presented below.

Screening Criteria

- Science topics currently not fully addressed
- Cross-agency and multi-group priority
- Feasible
- Promotes collaborative efforts

Science Prioritization Criteria

- Scientific merit
- High impact
- Timeliness/need/ready to proceed
- Risk assessment/opportunity cost

Outreach for Advice on List and Prioritization Criteria (June 2016 – February 2017)

The development of the Science Action Agenda is designed to be an open process; the Master List of management needs and science actions, therefore, were compiled through meeting with collaborative groups and referencing various related documents. Outreach meetings consisted of providing the respective organizations with the Science Action Agenda's purpose, development process, and a request for individuals to provide recommendations for management needs and associated science actions (see Table 1 for a list of organizations contacted). The draft list of criteria was also provided to individuals prior to each outreach meeting discussed above for review and input.

During the Bay-Delta Science Conference in November 2016, a Town Hall was held to receive input from the broader Delta community. Prior to the Town Hall, an online survey was distributed to receive input on additional science actions and management needs. Information from the online survey and Town Hall were compiled for inclusion in the draft list of science actions. A meeting was also convened with select faculty at UC Davis in December 2016 with expertise in social-ecological studies to discuss how to better incorporate human dimensions into the current list of science actions.

Applying Criteria to Refine List of Management Needs and Associated Science Actions (June 2016 – January 2017)

Once the Master List was finalized, science actions and management needs with similar messages or goals were merged, while those that were outdated or already completed were removed. The remaining 161 science actions and management needs were compiled into a spreadsheet, initially grouped by the 17 action areas identified in the ISAA organized by Delta Plan Chapters. Both the screening and prioritization criteria were applied to this set and those with the highest scores for prioritization criteria were retained. This resulting list of 27 science actions was presented to the Delta Science Program Lead Scientist and IEP Lead Scientist for review. With the lead scientists' suggestion, this list of science actions was further re-organized into five priority science action areas. This draft "short list" of 27 actions served as a starting point for further review and prioritization as described below.

The short list of science actions was presented to the Science Advisory Committee, the Delta Science Program and IEP Lead Scientists, and the IEP Council of Lead Scientists for input on whether the list was comprehensive or still in need of additional science actions. Comments from these groups were compiled and addressed.

Science Action Prioritization (March 2017)

At the Delta Agency Science Workgroup meeting in March 2017, the top two science actions needing immediate action from each topic categories were identified through a ranking activity. Prior to the March meeting, DASW members were asked to complete an online form that ranked the science actions under each action area based on the prioritization criteria described in the above section. At the meeting, the science actions were presented in the order determined from the online survey. The DASW

members were then requested to vote, by sticker method, on the top two science actions from each action area that were in need of and ready for immediate implementation in the next two years. Additional input such as ground truthing to ensure all the science actions were indeed not fully addressed and some minor wordsmithing were provided. The 12 priority science actions are included in the main document, while the remaining 12 Tier Two Science Actions can be found in Appendix A.

Table 1: List of Documents Used in Compiling Science Actions and Management Needs

Title of Document	*Associated Organization*
Adaptive Management Framework for the California Water Fix and Current Biological Opinions on the coordinated operations of the Central Valley and State Water Projects	California Department of Fish and Wildlife
Effects of Fish Predation on Salmonids in the Sacramento River - San Joaquin Delta and Associated Ecosystems	California Department of Fish and Wildlife, Delta Stewardship Council, National Marine Fisheries Service
2016 California Water Action Plan	California Natural Resource Agency
Increasing efficiency and effectiveness through collaboration: First triennial audit of implementing A Comprehensive Monitoring Program Strategy for California 2011-2014	California Water Quality Monitoring Council
Central Valley Improvement Plan 2017 Work plan Attachment 1: Memo on CVPIA Core Team Priorities	Central Valley Project Improvement Act
Central Valley Improvement Plan 2017 Work plan	Central Valley Project Improvement Act
Calendar Year 2015 Annual Progress Report to the Collaborative Science Policy Group	Collaborative Science and Adaptive Management Program/Collaborative Adaptive Management Team
Key Management Questions Regarding South Delta Salmonid Survival and Water Project Exports	Collaborative Science and Adaptive Management Program/Collaborative Adaptive Management Team
Effects of Water Project Operations on Juvenile Salmonid Migration and Survival in the South Delta	Collaborative Adaptive Management Team Salmonid Scoping Team
Flows and Fishes in the Sacramento-San Joaquin Delta: Strategic Research Needs in Support of Adaptive Management	Delta Independent Science Board
Improving Adaptive Management in the Sacramento-San Joaquin Delta: A Review by the Delta Independent Science Board	Delta Independent Science Board
Habitat Restoration in the Sacramento-San Joaquin Delta and Suisun Marsh: A Review of Science Programs	Delta Independent Science Board
DRAFT Workshop report—Earthquakes and High Water As Levee Hazards in the Sacramento-San Joaquin Delta	Delta Independent Science Board

Table 1: List of Documents Used in Compiling Science Actions and Management Needs	
Title of Document	*Associated Organization*
Delta Regional Monitoring Program Monitoring Design 2015	Delta Regional Monitoring Program
Challenges Facing the Sacramento-San Joaquin River Delta: Complex, Chaotic, or Simply Cantankerous?	Delta Science Program
High Impact Science Actions	Delta Science Program
Interim Science Action Agenda	Delta Science Program
Conservation Effects Assessment Project (CEAP)	Natural Resources Conservation Service
An Overview of Multi-Dimensional Models of the Sacramento-San Joaquin Delta	Delta Science Program
SBDS Chapter- Anadromous Salmonids in the Delta: New Science 2006–2016	Delta Science Program
SBDS Chapter-- Climate Change and the Delta	Delta Science Program
SBDS Chapter --Contaminant Effects on California Bay-Delta Species and Human Health	Delta Science Program
SBDS Chapter- Delta Smelt: Life History and Decline of a Once-Abundant Species in the San Francisco Estuary	Delta Science Program
SBDS Chapter—Nutrient Dynamics in the Delta: Effects on Primary Producers	Delta Science Program
SBDS Chapter--Perspectives on Bay-Delta Science Policy	Delta Science Program
SBDS Chapter- Predation on Fishes in the Sacramento–San Joaquin Delta: Current Knowledge and Future Directions	Delta Science Program
SBDS Chapter- The Delta as Changing Landscapes	Delta Science Program
SBDS Call Out Box: Climate Change	Delta Science Program
SBDS Call Out Box: Contaminants	Delta Science Program
SBDS Call Out Box: Flow	Delta Science Program
SBDS Call Out Box: Food Web	Delta Science Program
SBDS Call Out Box: Modeling	Delta Science Program
SBDS Call Out Box: Nutrients	Delta Science Program
SBDS Call Out Box: Delta Smelt	Delta Science Program
2016 Bay Delta Science Conference Town Hall Survey	Delta Science Program
Delta Plan	Delta Stewardship Council
Risk Analysis Methodology Delta Levees Investment Strategy	Delta Stewardship Council
Science Enterprise Workshop: Supporting and Implementing Collaborative Science	Delta Stewardship Council

Table 1: List of Documents Used in Compiling Science Actions and Management Needs	
Title of Document	*Associated Organization*
IEP Science Strategy –Needs for Near-term Science in Five Areas of Emphasis: Responses to Drought and Climate Change, Understanding Estuary Food Webs, Ecological Contribution of Restored Areas, Restoring Native Species and Communities, and Impacts of Non-native Species	Interagency Ecological Program (IEP)
Interagency Ecological Program 2016 Annual Work Plan Approved December 2015	Interagency Ecological Program (IEP)
An updated conceptual model of Delta Smelt biology: Our evolving understanding of an estuarine fish	IEP Management, Analysis, and Synthesis Team (MAST)
Diagnosis of a drought syndrome in the San Francisco Estuary	IEP Management, Analysis, and Synthesis Team (MAST)
Review of the IEP Delta Juvenile Fishes Monitoring Program and Delta Juvenile Salmonid Survival Studies	IEP SAG
Increasing the management value of life stage monitoring networks for three imperiled fishes in California's regulated rivers: case study Sacramento Winter-run Chinook salmon	IEP Salmon and Sturgeon Assessment, Indicators, Life Stages (SAIL)
Increasing the management value of life stage monitoring networks for three imperiled fishes in California's regulated rivers: case studies Southern Distinct Population Segment 2 of the North American Green Sturgeon and Sacramento-San Joaquin River White Sturgeon	IEP Salmon and Sturgeon Assessment, Indicators, Life Stages (SAIL)
Factors Affecting Growth of Cyanobacteria With Special Emphasis on the Sacramento-San Joaquin Delta	Nutrient Research Strategy Science Work Group
Factors Controlling Submersed and Floating Macrophytes in the Sacramento-San Joaquin Delta	Nutrient Research Strategy Science Work Group
Recommendations for a Modeling Framework to Answer Nutrient Management Questions in the Sacramento-San Joaquin Delta	Nutrient Research Strategy Science Work Group
Draft Research Plan 2015	State and Federal Contractors Water Agency's coordinated science program
SFCWA Draft Salmon Questions	State and Federal Contractors Water Agency's coordinated science program
2016 Comprehensive Conservation and Management Plan	San Francisco Estuary Partnership
Multi-Year Plan 2016 Annual Update	San Francisco Regional Monitoring Program
Primary Production in the Sacramento-San Joaquin Delta	SFEI/DSP

Table 1: List of Documents Used in Compiling Science Actions and Management Needs	
Title of Document	*Associated Organization*
Monitoring of Constituents of Emerging Concern (CECs) in California's Aquatic Ecosystems - Pilot Study Design and QA/QC Guidance	Southern California Coastal Water Research Project
Wetland Status and Trends Program Implementation Proposal July 30, 2014	Southern California Coastal Water Research Project
Past, Present and Future Approaches to Incidental Take	US Fish and Wildlife Service
Integrated Modeling for Adaptive Management of Estuarine Systems	UC Davis Center for Watershed Sciences
Delta Region Area wide Aquatic Weed Project	UC Division of Agriculture and Natural Resources
Wildlife Corridors for Flood Escape on the Yolo Bypass Wildlife Area	Yolo County Conservation District

Table 2: List of Organizations that Provided input on Management Needs and Science Actions to include in the Science Action Agenda
Collaborative Adaptive Management Team
Delta Agency Science Workgroup
Delta Independent Science Board
Delta Plan Interagency Implementation Committee
Delta Regional Monitoring Program
Interagency Ecological Program
Scientific Advisory Committee
UC Davis Social Science Faculty
Town Hall at the Bay Delta Science Conference

Table 3: List of Sources Investigated to Guide Development of Prioritization Criteria
Collaborative Adaptive Management Team
Great Lakes Commission
Interagency Ecological Program Decision Making Criteria (Sean Hayes)
Interagency Ecological Program Science Agenda Prioritization and Implementation Strategy
Interim Science Action Agenda Criteria
National Research Foundation Proposals and Award Guidelines
NOAA Alaska and Southwest Fisheries Science Centers
Puget Sound Partnership
South Florida Ecosystem Restoration Task Force

Appendix C: Science Action Prioritization Criteria for the Science Action Agenda

The following is a description of 1) the screening approach for the initial set of management questions/needs and science actions that promote science-support for Delta decision-making relevant to achieving the coequal goals and implementing multi-agency and organizations' actions, and 2) the criteria and approach for prioritizing science actions. Prioritizing actions is complicated and challenging; however, with limited resources, it is an essential task. No single prioritization approach exists across other major complex systems or disciplines.

Creating the List of Management Needs and Science Actions

The Master List of management needs and science actions that would address them were be assembled from those identified in the Interim Science Action Agenda and other collaborative documents such as the IEP Science Strategy, DRMP Monitoring Design, and State and Federal Contractors Water Agency Science Research Plan, CAMT Work Plan, and SBDS. Please see Table 1 of Appendix B for a full list of documents used in compiling the list.

Refining the Master List

The Master List was refined by Delta Science Program staff by applying the following screening criteria with ongoing guidance from the SAC and representatives of the Delta policy, management, and science community.

Screening Criteria

1. Science Topics Not Fully Addressed
    a. Forthcoming decisions requiring information to evaluate best alternative: are only partially supported – alternatives and their associated uncertainties haven't been fully explored.
    b. Management need: is only partially addressed by an agency, set of agencies, or groups and thus require further attention from the broader Delta community.
    c. Science action: is only being partially funded or addressed by an agency or group and requires cross-agency support or is currently not being addressed by any group. Science actions that are well supported or in the final stages of implementation do not fall under this criterion.
2. Cross-Agency and Multi-Group Priority
    a. Management need: is relevant to multiple agencies and organizations throughout the Delta and/or fulfills the mission of multiple groups.
    b. Science action: is not site specific or single agency focused and integrates the research and science goals of the larger Delta science community.
    c. The science action is linked to a high-priority policy issue that has cross-agency implications such as the California Water Action Plan, EcoRestore, WaterFix, the Delta Plan, a new Governor's initiative.
    d. Executing the science action will help address achievement of the coequal goals in the Delta Plan.

e. The outputs of the action will be directly used in water management or ecosystem management; the action has broad agency and stakeholder support.
f. The action is included in multiple priority lists by science programs that carry out research and monitoring in the Delta.

3. Feasible
    a. The action can likely proceed given legal, fiscal, and institutional considerations.
    b. The capacity to carry out the research successfully is well established and described.

4. Promotes Collaborative Efforts
    a. Implementing the science action will provide opportunities to serve the needs of multiple agencies and organizations.
    b. The science action is synergistic with existing efforts and will support multi-agency collaboration.

Prioritizing the Refined List

Once the management needs and science actions list is refined, the science actions within each management need were prioritized using the following criteria.

Science Prioritization Criteria

1. Scientific Merit
    a. The action is based on a sound rationale (e.g., has a high degree of support from relevant science communities and has high potential to advance knowledge).
    b. Recommended by the Delta Lead Scientist, IEP Lead Scientist, Delta Independent Science Board, or an independent peer review panel.

2. High-Impact
    a. The action is useable by one or more key agencies within a four-year time frame.
    b. Identifies and addresses current or anticipated gaps in knowledge relevant to multiple agencies.
    c. Involves integrating existing data from individual agencies spanning various geographical locations.
    d. Identifies emerging issues requiring a rapid delta-wide assessment to develop management needs.
    e. Supports synthesis activities that cross multiple existing programs or agency missions.
    f. Supports science infrastructure needs (the action supports the Delta science enterprise, provides tools, facilities, or professional development for scientists).
    g. Has a high potential to address and resolve areas of scientific conflict.

3. Timeliness/ Need
    a. The action is ready for further development and the opportunity for progress is high.
    b. The project has partial support and commitments that can be greatly enriched by focused short-term attention.
4. Risk Assessment/ Opportunity Cost

a. Not taking this action today would pose a severe risk to core scientific, technical and organizational capabilities to address management needs today and in the future.
b. Addressing this scientific topic is an immediate opportunity for innovation and scientific advancements with high potential for critical new knowledge of the Delta.